

REMARKS / ARGUMENTS

Amendments to the Claims

Claim 1 is amended to specify that the concentration of hydrogen gas added with the hydrocarbon is up to concentrations of 7 mol%. The basis for this amendment is found in originally filed Claim 6, which is now canceled from the application.

Claim 7 is amended to depend from Claim 1 rather than from now canceled Claim 6.

Claims 18 – 20 are also now canceled from the application. Claim 12 was previously canceled from the application.

Claims 1 – 5, 7 – 11, and 13 – 17 remain in the application.

Summary of the Present Invention

The present invention is a modification of the Houdry process for the dehydrogenation of aliphatic hydrocarbons, whereby the cycle is extended, or lengthened, and hydrogen recycle is added to the feed. The combination of the extended cycle with the hydrogen recycle results in a surprising stabilization of the production rate in the dehydrogenation process.

Remarks Regarding Claims Rejected Under 35 USC §103(a)

The Examiner has rejected Claims 1 – 11 and 13 – 20 under 35 U.S.C. §103(a) as obvious in view of Houdry (U.S. Patent 2,419,997, “the ‘997 patent”) and Herbstman (U.S. Patent 4,409,417, “the ‘417 patent”).

The examiner contends that it “would have been obvious to one having ordinary skill in the art to change the contact time during the reaction as suggested by Houdry because changing this time changes the heat balance.” The examiner also contends that it “would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the process of the prior art by including hydrogen in the amounts claimed in the process as suggested by Herbstman because formation of carbonaceous deposits will be reduced.”

Applicant respectfully contends that these two prior art references do not render the claims of the present application obvious. If anything, they support the non-obviousness of the claims of the present application.

The Houdry patent was issued in 1947 and the Herbstman patent was issued in 1983, but it was not until the present application that it was obvious to use the teachings from these two patents in combination. In fact, even the inventors – persons with at least a level of ordinary skill

in the art – acknowledged in the specification of the present application that “[t]he combination of the extended cycle with the hydrogen recycle results in a surprising stabilization of the production rate in the dehydrogenation process.” (Emphasis added; present application specification, page 3, lines 4 – 5.) It is precisely this combination of elements – lengthened cycle time plus the addition of a relatively small amount of hydrogen with the hydrocarbon – that is the invention as set forth in the claims of the present application.

The examiner is correct that Houdry teaches that the contact time can be changed to affect the heat balance. But, the applicant contends that the examiner is incorrect that this would translate to extending the cycles, and thus the contact time, in the standard Houdry process because, as noted in the present application specification, page 5, line 9 and lines 13 – 15, the amount of coke produced increases with the extended cycle, and “the higher coke make is detrimental to the life of the catalyst and manifests itself in decreased production of the desired product as the catalyst ages. Thus, while the extended cycle improves conversion, the increased coke makes the extended cycle process less attractive.” In view of these objective results, there would be no motivation, nor a reasonable expectation of success, to modify the cycles as taught by Houdry by extending their length.

The examiner is also correct that Herbstman teaches that hydrogen can be added with a hydrocarbon feed to suppress the formation of hydrogen-deficient, carbonaceous deposits on the catalytic composite, in addition to lowering the partial pressure of the dehydrogenatable hydrocarbon. Specifically, Herbstman teaches that “[h]ydrogen is the preferred diluent for use in the subject dehydrogenation method ... Ordinarily, hydrogen is utilized in amounts sufficient to insure a hydrogen to hydrocarbon mole ratio of about 1:1 to about 20:1, with best results obtained in the range of about 1.5:1 to about 10:1.” (Column 4, lines 8 – 20.) However, Herbstman is silent about how, and when, he determines the mole ratio of hydrogen to hydrocarbon. Looking to the examples of the ‘417 patent as a guide, it would seem that Herbstman’s comments about the hydrogen to hydrocarbon mole ratio do not apply to the feedstream as it enters the catalyst bed. Herbstman presents seven examples demonstrating his process using isobutane and hydrogen. For Examples I – III and V – VI, Herbstman uses “isobutane (8 WHSV) and hydrogen (1.0 CFH, cubic feet per hour, corresponding to a mole ratio of hydrogen to hydrocarbon of 0.67:1)...” (Column 5, lines 43 – 45.) This hydrogen concentration is more than 30% below his recommended minimum ratio of 1:1. Herbstman further notes that Example VII “represents the best mode known to me at this time of practicing the process of this invention...” and goes on to explain that the charge to the reactor is isobutane (8 WHSV) and hydrogen (1.0 CFH)

corresponding to a mole ratio of hydrogen to hydrocarbon of 0.73:1, and 0.4 CFH ammonia. (Column 6, lines 21 – 28.) Again, this mole ratio of hydrogen to hydrocarbon is significantly below the recommended minimum ratio of 1:1. Thus, Herbstman cannot be referring to the hydrogen to hydrocarbon mole ratio of the feedstream as it enters the catalyst bed. And because Herbstman fails to refer to the hydrogen to hydrocarbon ratio except for the comments in column 4 (including the summarized version in the column 4 table) and in the contradictory Examples, it is unlikely that one skilled in the art would find the teachings related to the hydrogen to hydrocarbon ratio to be enabling.

Moreover, based on the results from Herbstman's examples, particularly when taken in combination with the teachings of Houdry (the '997 patent), one skilled in the art would not be inclined to add hydrogen into a hydrocarbon feedstream if the intent was to maintain a high product yield and high selectivity. The examples of Houdry teach using hydrocarbon feeds without added hydrogen. Looking at Houdry Examples III and V, when hydrogen is not present in an n-butane feedstream¹ and the n-butane is present as 94 – 96 wt% of the feed, one can expect yields of n-butene to be 38.8 – 44.1 wt% of the product mix, with selectivity at about 73 ± 1%. (See Houdry, Column 7, line 30 – Column 8, line 28 and Column 9, line 26 – Column 9, line 64.) In contrast, when Herbstman adds hydrogen to an isobutane feedstream without also adding ammonia, his best yield is 23.8 wt% isobutylene with a selectivity of 72.3 – 78.2% (see Herbstman, Column 6, Table). When the hydrogen concentration in the isobutane feedstream is increased (Example IV), both the yield and selectivity significantly decrease (yield, 19.6 wt%; selectivity, 59%). Thus, in view of these objective results, there would be no motivation, nor a reasonable expectation of success, to intentionally add hydrogen, even very low concentrations of hydrogen, to a hydrocarbon feedstream which was to be subjected to a dehydrogenation process.

Further, in the present invention, the amount of hydrogen added to the dehydrogenation stage with the hydrocarbon to be dehydrogenated is well below the ratio taught by Herbstman. Applicant still maintains that the teaching of Herbstman with respect to the hydrogen to hydrocarbon ratio is not enabling. But, for the purposes of discussion, Applicant will assume that the teaching of Herbstman is to be interpreted to mean that the hydrogen to hydrocarbon ratio is determined for the incoming feedstream and that ratio may be as low as 0.67:1. In this case, the concentration of hydrogen taught by Herbstman is, at a minimum, nearly 10-fold higher than the hydrogen concentration of the present application. In the present application, hydrogen is added at concentrations up to 7 mol% or at an added concentration of up to 0.075:1 (7 mol % hydrogen :

¹ Although not identical to Herbstman's isobutane, Houdry's n-butane provides a closer comparison than the mixed hydrocarbons reported by Houdry.

93 mol % hydrocarbon). This hydrogen is added into the dehydrogenation step (e.g. Claim 1, step (d)), where an aliphatic hydrocarbon is delivered to a reduced, evacuated catalyst bed, and then the hydrocarbon is dehydrogenated as it passes through the catalyst bed. There is no teaching or suggestion in Herbstman that concentrations of hydrogen as low as 7 mol% would be effective for suppressing coke formation, and thus, there would be no motivation to add, nor any reasonable expectation of success from adding, these low levels of hydrogen to the hydrocarbon feed in an extended cycle Houdry process.

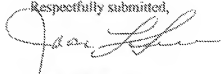
Applicant contends, therefore, that modifying the 1947 Houdry process by the two additional elements, as set forth in independent Claims 1 and 13,

- (1) extending the cycle length by the introduction of a delay of at least one predetermined time interval into at least one stage of the cycle; and
- (2) introducing hydrogen gas, at concentrations of up to about 7 mol% H_2 , into the reaction at stage (d),

results in a novel and non-obvious process for the dehydrogenation of aliphatic hydrocarbons. Neither the '997 patent nor the '417 patent, alone or in combination, teach or suggest that in the Houdry process the reaction cycle times can be extended if hydrogen gas is introduced to the reactors along with the hydrocarbon that is to be dehydrogenated. There is no motivation in either patent to suggest these modifications. There was no reasonable expectation of success.

For the reasons set forth above, Applicant respectfully requests that a timely Notice of Allowance be issued in this case.

Respectfully submitted,



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